Extent and Spatial Distribution of Salt Affected Soils of Meki-Zeway Area of Central Rift Valley – Ethiopia

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Introduction

Wide spread occurrence of salt-affected soil in Ethiopia has been well documented (Hawando, 1995; Kidane *et al*. (2006). Large tract of land size was reported to have been salt affected (saline, saline sodic and sodic) and mainly concentrated in the Rift Valley and Wabi Shebelle River Basin (Fantaw, 2007). According to Sissay (1985), salt-affected soils increased from 6 to 16 % of the cultivated land area of Ethiopia. Salt affected soils are soils that have been adversely modified for the growth and production of most crop plants due to the presence of excessive concentrations of either soluble salts, or exchangeable Na, or both. Excessive accumulation of soluble salts or exchangeable Na impose a stress on growing crops that can lead to decreased production and productivity and, in severe cases, complete crop failure and total loss of land value.

Meki and Zeway irrigated farm areas located in the Central Rift valley zone of the Great Rift Valley system of Ethiopia. The area is known for the production of most important vegetables grown under irrigation which include onion, tomato, haricot beans, cabbage and broccoli (Moti, 2002). Soils of the area are naturally salt-affected and prone to secondary salinization. According to Meron (2007) buildup and expansion of salinization and sodiciation in particular is becoming potential threat sustainability of irrigated farms of the area. In past only limited studies has been conducted in the area which generally focused on soil taxonomic classification and related aspect where detailed information on extent and spatial distribution of salt-affected soils in the area is lacking. Detection of salinization, assessment of the degree of severity and the extent, particularly in its early stage is vital in terms of sustainable agricultural management. Hence, identification types of salt affected soils and determination of extent of salinity and sodicity becomes critically important to enable undertaking of appropriate measures accordingly. This study, therefore, was executed with objective that to investigate extent and spatial distribution of salt-affected soils of Meki-Zeway irrigated farm areas.

Materials and Methods

Characteristics of the study area

Meki-Zeway site is located at 7˚ 59' 05" N Latitude and 38˚43'20" E Longitude which is found at 160 km south of Addis Ababa, and at an altitude of 1628 masl. The area received average annual rainfall of 778 mm and has a mean annual temperature ranging from 14.4 to 27.0°C. The agro-climatic conditions allow farmers to grow onion (Allium cepa), tomato (Solanum lycopersicum) and maize (Zea mays). The soil type of the study site is Haplic Andosols, Typic Haploxerands (Zewdie 2004) and it is of sandy loam texture.

Soil Sample collection

Prior to sample collection reconnaissance survey was conducted to investigate extent of soil variability/homogeneity on the basis of variations in landscape, land-use and visually observable soil features from which method of sampling and sample quantity required to represent study area was determined. Grid method of sampling was used and a total of 270 auger samples were collected at a soil depth of 0-30, 30-60 and 60-90cm covering a total land size of 9,718 ha. Then, the soil samples were bagged, properly labeled, and dispatched to the laboratory for analysis.

Sample Preparation and Analysis

The soil samples, thus collected were dried in shade, powdered with wooden mallet, passed through 2 mm sieve and stored in clean sample box for analysis (Jackson, 1973). Following standard test procedures soil samples were analyzed for selected physico-chemical properties at Debre Zeite Agricultural Research laboratory. Soil pHe and electrical conductivity was measured from saturated paste extract using a digital pH-meter and digital EC meter, respectively. Cation exchange capacity (CEC) and exchangeable bases were determined from neutral normal ammonium acetate extracts. Na and K were determined by flame photometry (Jackson, 1973). Mg and Ca were determined by titration method. Particle size distribution was determined by hydrometer method. Derived parameters; ESP was computed as the percentage of the sum of exchangeable bases and exchangeable Na to the CEC of the soil following formula given below:

$$ESP\ (\%) = \frac{Exchangeable\ sodium\ (Na^{+})}{CEC} * 100$$

Where, concentrations are in cmol $_{(+)}$ kg^{-1} of soil.

Classification and Mapping

The soils were classified into different salt affected soils according to the standard guidelines by Richards (1954). The spatial mapping of the soil salinity and sodicity parameters was carried out in GIS (ArcGIS 9.2) following Geostatistical analysis that employs the use of simple point kriging and simulations (ESRI. (2010).

Result and Discussion

Particle Size Distribution

The results of the particle size analysis indicate that the soils Meki-Zeway irrigated farm areas were sandy loam to loamy textured soils. The proportion of clay particle varied between 14 to 25% while sand and silt varied from 31 to 70% and 13 to 42%, respectively. Result revealed that the sand content in the soils of studied area was very high and silt/clay ratios were greater than 0.76 indicating that the soils are relatively young with high degree of weathering potential. This could be due to the fact that parent materials around Zeway are composed of volcanic rocks, with alkaline lavas, ashes and ignimbrites, mainly of Tertiary and younger age (Meron 2007) which can eventually lead to young soils with courser texture.

Chemical characteristics

Soil reaction (pHe)

The soil pHe values of saturation paste extract (pHe) for Meki-Zeway irrigated farms varied from 6.9 to 9.3 with the mean value of 7.9 for the upper 0-30 cm soil depth (Table 1) and had shown a general tendency of increasing with soil depth indicating increasing alkalinity at lower sub soils.

Table 1. Mean and range values of soil pHe, ECe and ESP for Meki-Zeway irrigated farm areas

Soil depth (cm)	pHe			ECe (dS/m)			ESP (%)		
	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
Min	6.9	7.2	7.9	0.20	0.19	0.21	3	5	7
Max	9.0	9.7	10.3	15.30	12.98	7.56	58	65	76
Mean	7.9	8.3	8.7	3.08	2.30	1.93	12	22	34

Out of the total investigated area, farms with neutral and slightly alkaline reaction constitute about 15.4 and 40.40%, respectively for the upper 0-30cm soil layer. For the same upper soil layer farms having soils reaction rated as moderately and strongly alkaline constitute about 40.10% whereas only 4.10% appeared to had strongly alkaline soil property. The majority of soil samples from Meki irrigated farm area contained pHe values less than 7.8 whereas larger proportion of samples from Zeway farm area had pHe values greater than 7.8 indicating general alkaline reaction (Figure 1).

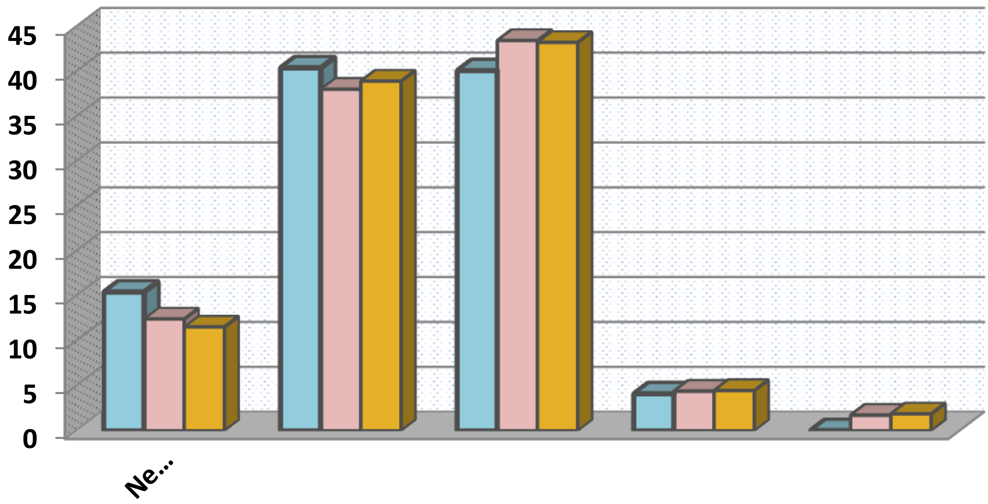

Figure 1. Percentage proportion of farm area with different soil reaction class

The spatial map of the soil reaction based on pHe (Figure 2) clearly depicts that larger proportion of Meki irrigated farm area constitute soils with neutral to slightly alkaline property. On other hand; soils of Zeway irrigated farms were seen to be dominantly alkaline where larger portion of the area classified' as moderately to strongly alkaline reaction which is in agreement with findings reported by Meron (2007). pHe is one of the most important parameter measured in soils as most of chemical reactions and microbial activities in the soil are largely governed by the soil reaction. A normal pHe for soil ranges from 6.5 to 8.0; a pHe beyond this range may result in nutritional and growth problems. The availability of essential nutrients such as N, P, K, especially P is largely dependent on pHe. A neutral soil has the optimum condition for crop growth with favorable supply of essential nutrients whereas a soil with pHe in the medium to strongly alkaline range may indicate the possible deficiency of micro-nutrients and P-fixation as Ca-phosphate. Alkaline reaction may also reflect sodicity, poor drainage and accumulation of alkaline earth carbonates.

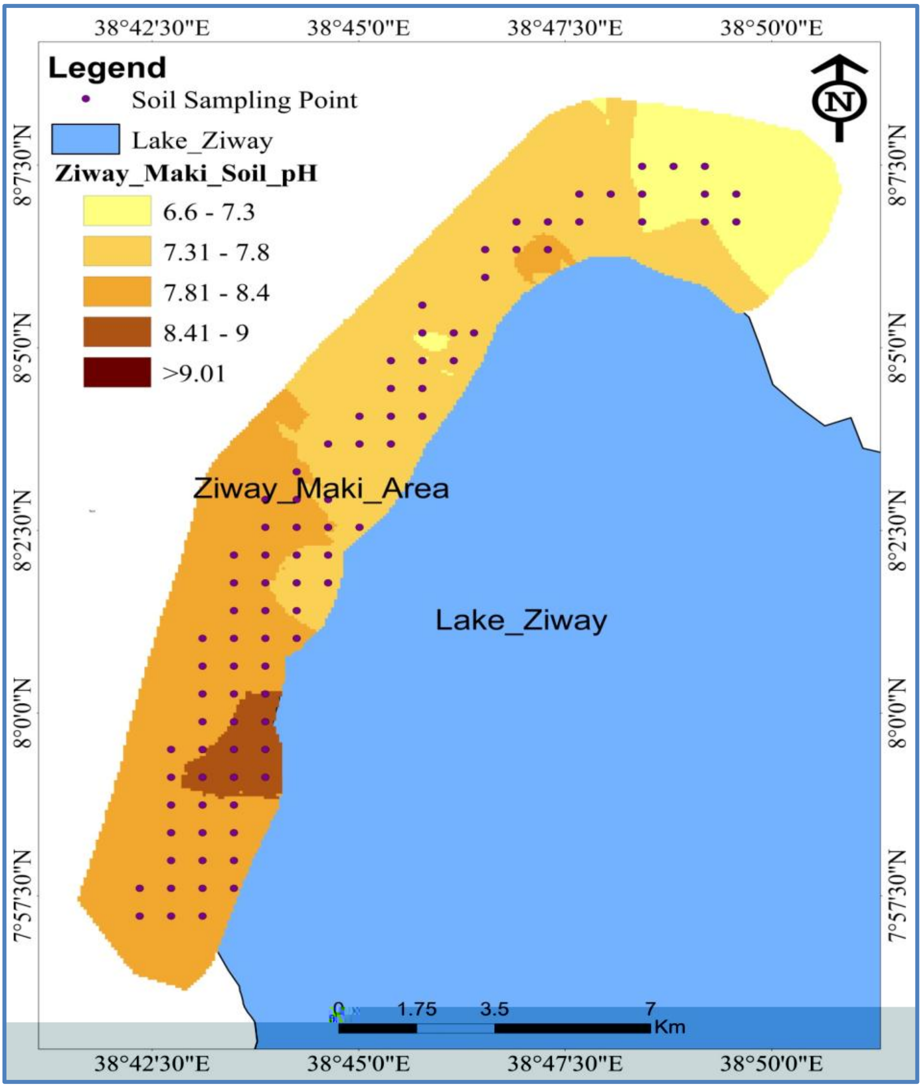

Figure 2. The spatial map of the soil reaction based on pHe

Electrical conductivity (ECe)

The overall range values of ECe, varied between 0.20 to 15.30 dS/m for the upper 0-30cm soil depth with a mean values 3.08 dS/m (Table 1) which could be rated as normal soil (free of excess salt) to moderately saline soil condition. Soil ECe values had generally shown to had a decreasing trend with increasing soil depth being surface soil contained relatively higher salt accumulation. However, around the riverbank in Zeway horticultural state farm, one is able to see the Fisseha (1998) indicated occurrence of visually observable solonchack with white salt incrustation on surface in and around Zeway horticultural state farm areas. Such a pattern is explained by the upward movement of ions with capillary water to the upper soil layer from the bottom laying layers. This might be due to higher evapotranspiration than precipitation in this area. The ECe value indicated that the soils of Zeway area are salt affected (Havlin et al., 1999). The same distribution patterns were observed in water soluble Na^{+}, Ca^{2+} and Mg^{2+} where these cations decline with increasing depth. Anion distribution in soil depth also followed the same patterns as ECe does. Na from the cation side and Cl from anion side were the dominant ions indicating that these ions are the major salt species could be contributing to salinity problem.

Out of the total 9,718 ha of farm area studied, about 17% (1,639 ha) had ECe values between 4 and 8 dS/m for the upper 0-30 cm soil layer which could be rated as moderately saline soil class where as 82 % (7,997 ha) of the area contained ECe values less than 4 dS/m and generally classified as free of excess salt having no adverse effect on growth and productivity of most crops (Figure 3). High concentration of complex inorganic salts present in the growing medium, retard the growth in most of the crop plants depending on the growth stages and the salt tolerance or avoidable mechanism of the plant tissues (Ashraf *et al.*, 2002).

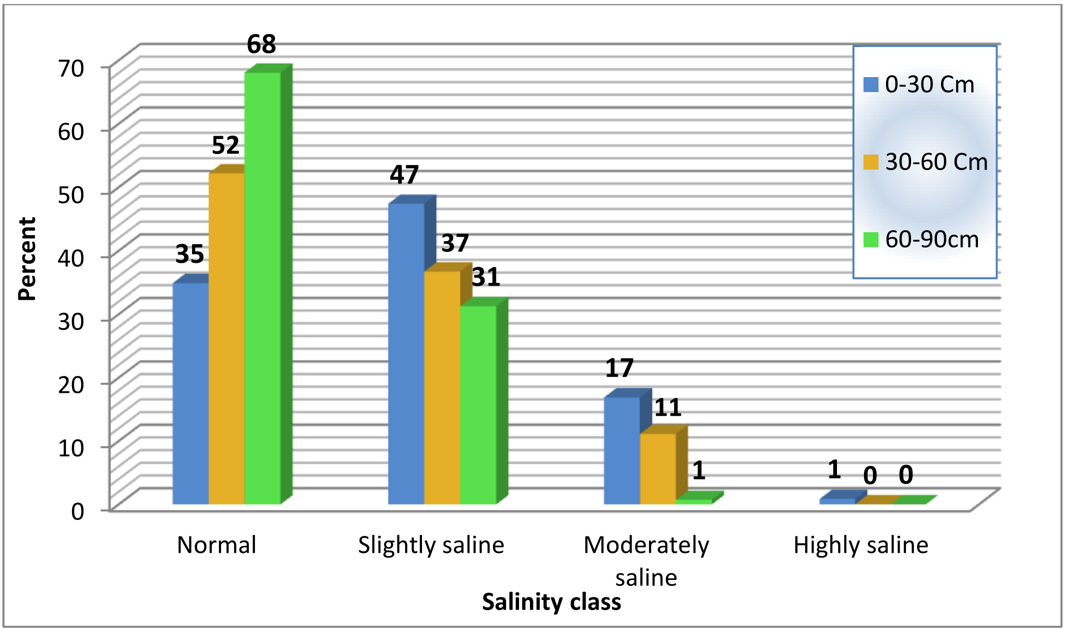

Figure 3. Percentage proportion of farm area with different soil salinity class

Exchangeable sodium Percentage (ESP)

The range values of ESP varied between 3 and 58 % with mean value of 13 % for the upper 0-30 cm soil layer (Table 1). The ESP regularly increased with increasing soil depth indicating lower soil layer had more sodic property. An ESP of 15 % is generally recognized as a limit above which the soils are characterized as sodic (alkali) (Richards, 1954). This limit, though tentative, has been increasingly found useful because many soils show a sharp deterioration in physical properties around or above this ESP. Regarding percentage proportion of farm area classified into different ratings result revealed that normal (non-sodic) soil constitute about 71% of total farm area studied while farms with slight to moderate and high to very high sodic soil property was found to had about 25 and 4 % of area coverage, respectively (Figure 4).

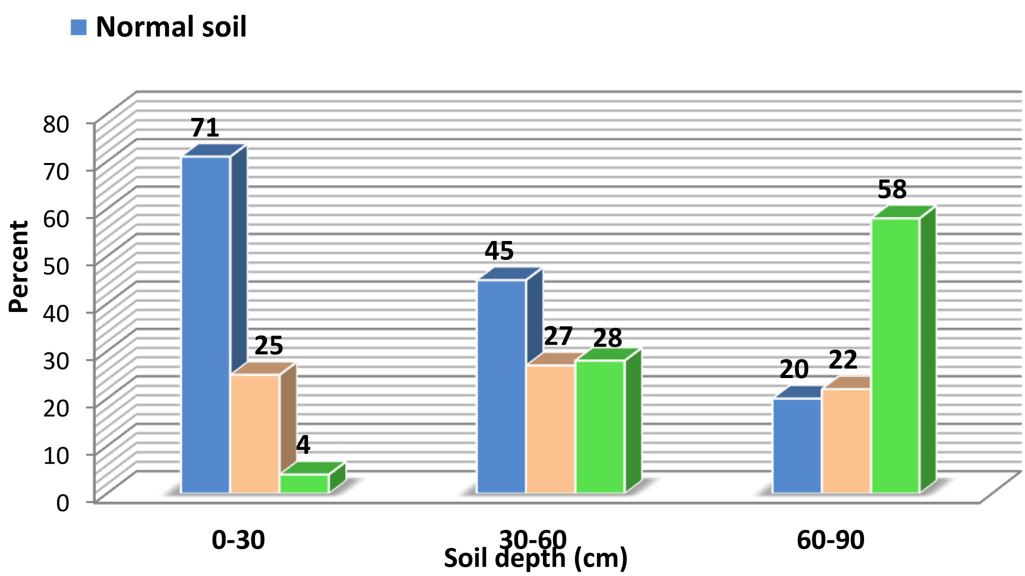

Figure 4. Percentage proportion of farm area with different soil sodicity class

Excess sodium can cause nutritional disorders by reducing uptake of calcium and magnesium. In addition to affecting plant nutrition, sodium is known to adversely affect the soil physical conditions imparting low permeability to water and air and accumulation of black solubilized organic matter on the surface. This limits water and air infiltration and root penetration (Gupta and Abrol, 1990). The magnitude of adverse effect imposed by sodicity, however, varied according to variation in some soil factors.

Figure 5. Spatial map of soil sodicity based on ESP values

ambient electrolyte concentration in the soil solution and prevailing clay type and content.

Extent of salinity and sodicity problems

Present study revealed wide spread occurrence of salt-affected soils in Meki and Zeway irrigated farm areas. Fig. 6 & 7 present the extent of salt-affected soils in terms of area coverage and spatial distribution, respectively.

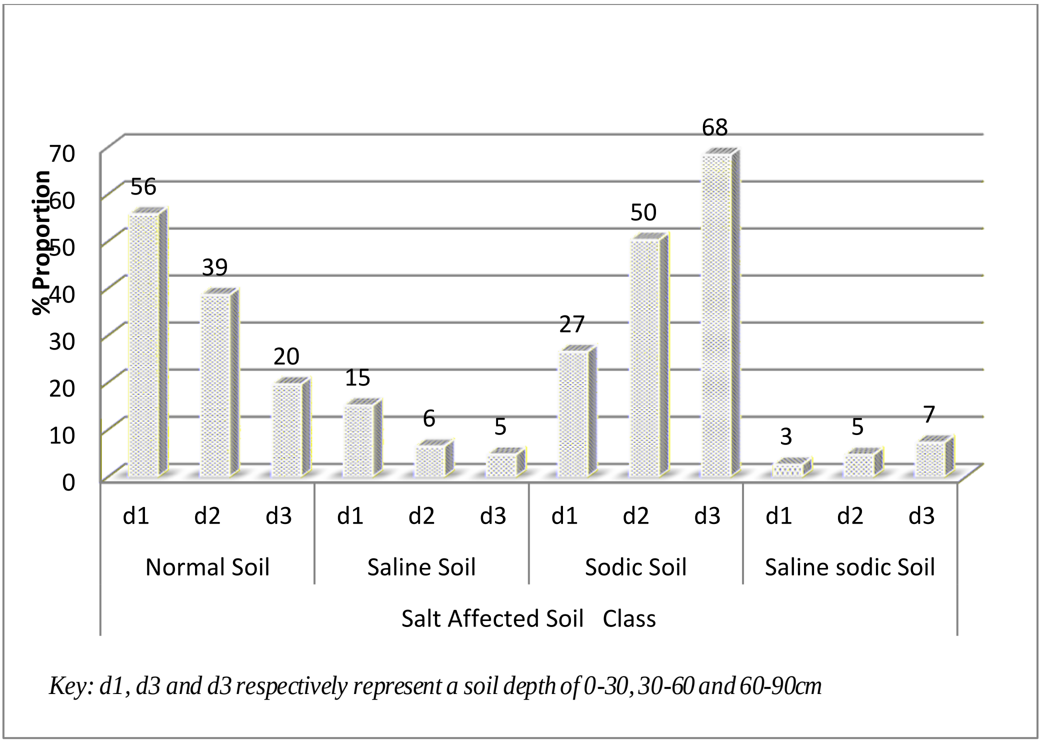

Figure 6. Percentage proportion of different salt-affected soil classes at three soil layers

Based on the Richards (1954) classification of salt-affected soils; out of the total investigated area of Meki-Zeway irrigated farms about 1,471, 2,575 and 251 ha accounting for 15, 27 and 3% of farm size (upper 0-30 cm soil layer) belong to the saline, sodic, and saline-sodic soil class, respectively. Close to 5,422 ha (56 %) farm area belongs to normal soil class. The extent of alkalinity and sodicity problems seems to be more important for irrigated farms of Zeway than Meki area in terms of area coverage and magnitude of the problem. With increasing soil depth from the upper 0-30 to lower 60-90 cm soil layer soil alkalinity and sodicity problems had also shown to increase consistently.

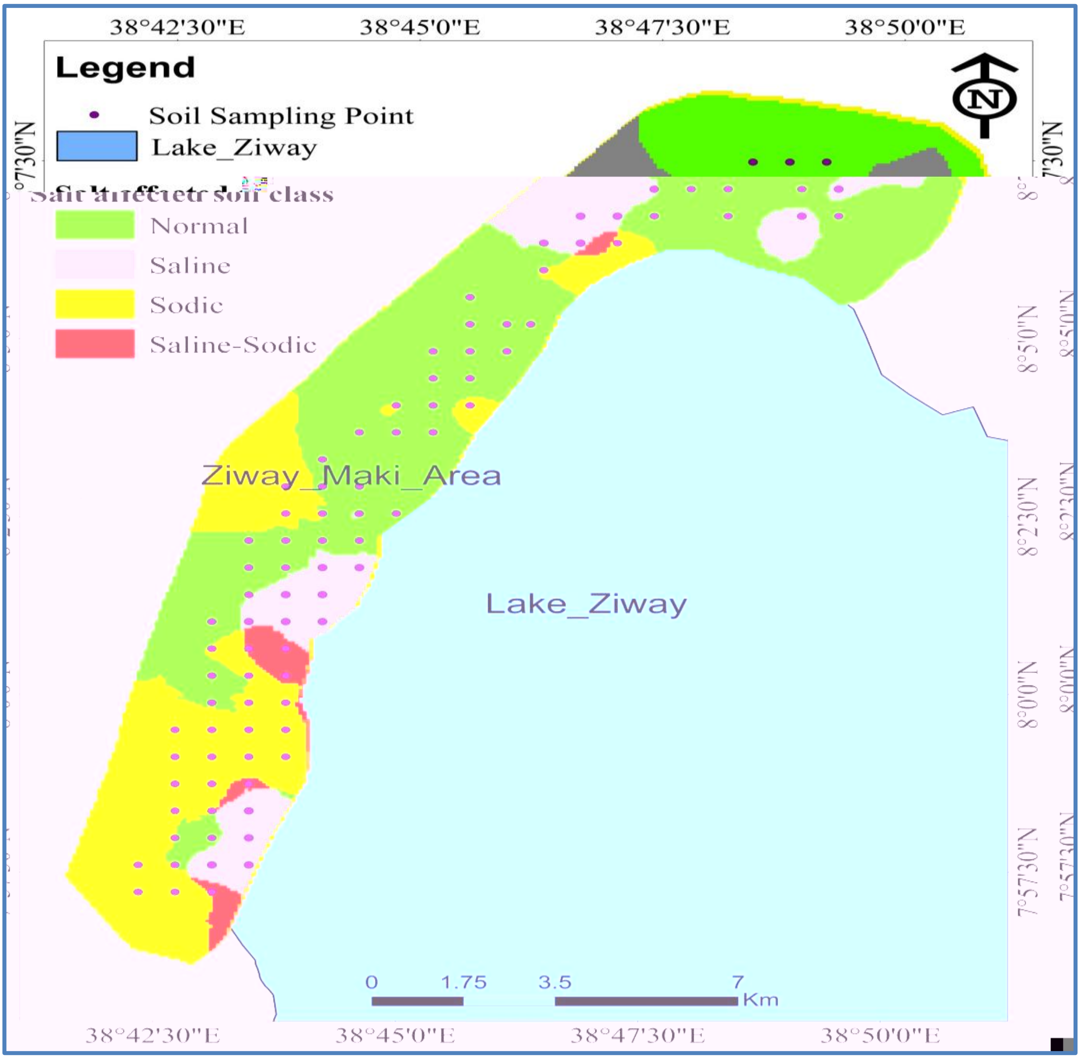

Figure 7 Spatial map of salt-affected soils for Meki-Zeway irrigated farm areas. It should be noted that those farm areas classified as non-sodic and non-saline soils for the above 0-30 cm soil layer and regarded as normal soil had contained relatively appreciable level of ESP and free Na in soil solution phase at lower layers indicating potential risk of buildup and expansion of salt-affected soils with time. Soils containing an ECe value less than 4dS/m are general regarded as normal soil. From Figure 3 it can be seen that about 47 % of the area had soils with an ECe values between 2 and 4 dS/m which were classified as slightly saline soil are prone to secondary salinization to be in near future unless proper mitigation are addressed in good time.

Conclusion and Recommendation

The study suggest some limited part of farms under investigation had shown to contain excess accumulation of free salt in which 15 % out of the total area could be classified as saline soil. The soils lack appreciable quantities of neutral soluble salts but contain measurable to appreciable quantities of salts capable of alkaline hydrolysis, substantial area of irrigated farms exhibit alkaline soil property that range from moderate to strongly alkaline reaction and tend to increase with increasing soil depth. The study also revealed that majority of farm areas contained soils with sodic character that increased with increasing soil depth. As a result, implementing appropriate soil salinity management practice at Meki Zeway is required for sustainability of agriculture in the area. Ground water is claimed as a secondary cause for buildup, therefore restriction should be on use of brackish ground water for irrigation unless treated or blended with good quality water and further research to deliver appropriate management options that suit local socio-economic conditions is required

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